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Our Ref.: M-15069

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Subject: **Seismic Refraction Surveys at Bob's Lake Dam Site, Bolingbroke (ON)**

Dear Sir,

Geophysics GPR International Inc. has been mandated by CIMA+ to carry out seismic refraction surveys on three lines across the Bob's Lake North end, in Bolingbroke. The geophysical investigations aimed a general rock quality assessment with depth from surface recognisance for the optimization of the location of the new dam/weir.

The surveys were carried out from July 21st to 23rd 2015, by Mr. Charles Trottier, M.A.Sc., phys., Mr. Nicolas Beaulieu, Eng., and Mr. Jérémie Dufour, train. Figure 1 shows the regional location of the site, and Figure 2 illustrates the location of the seismic lines. Both figures are presented in the appendix.

The following paragraphs briefly describe the survey design, the principles of the test methods, and the results in graphic format.

ISO 9001

Method Principle

The seismic refraction method relies on measuring the transit time of the wave that takes the shortest time to travel from the shot-point to each geophone/hydrophone. The fastest seismic waves are the compression (P) or acoustic waves, where displaced particles oscillate in the direction of wave propagation. The energy that follows this first arrival, such as reflected waves and transverse (S) waves, is not considered under routine seismic refraction interpretation.

The calculations of the seismic data were done using the Hawkins method. It allows the computation of rock depth and rock mechanical quality for every geophone/hydrophone. The method is based on the closure times of the inner shots. It allows the calculation of the true velocities of the upper portion of the bedrock, using the apparent seismic velocities, with the information provided by the outer shots.

Figure 3 illustrates the basic operating principle for refraction surveys. A more detailed description of the theory and processing steps can be found in *Technical Report E-73-4 Seismic Refraction Exploration* for Engineering Site Investigation, B.B. Redpath, NTIS, 1973 and, *Shear wave velocity measurement guidelines for Canadian seismic site characterization in soil and rock*, Hunter, J.A., Crow, H.L., et al., Commission géologique du Canada, Dossier public 7078, 2012.

Survey Design

As no stakes and/ or obvious marks were present on the site, the seismic lines were located from theoretical coordinates and hand-held GPS, considering existing land constrains.

On land, geophones were installed along the topography 3 meters apart, while across Bob's Lake, hydrophones were installed 3 meters apart, horizontally (cf. Figure 4) from a hanging cable across the lake.

On shores, the seismic source used was a 20 lb sledge hammer, striking a steel plate for electrical close contact triggering, with stacking for S/N ratio enhancement. Over the river, the seismic source was a buffalo-gun (blank black powder 12 gauge shells).

RESULTS

The surface topographic references were made with the A000492B-AR001.DWG drawing and the correlated field observations. The planimetric coordinates system is UTM, zone 18. The bathymetric measurements were realized with a fathometer GARMIN ECHO 101, and localized over each installed hydrophone.

The seismic refraction profiles results are presented in Annex. The integration of these results was realized to figure the general trends of the rock elevation (figure 8), and the rock mechanical quality, related to V_P (figure 9).

After a geotechnical report of 1984, the rock mechanical quality became an important concern for the new location of the dam. As illustrated by the Figure 9, the rock seismic velocity appears to be lower, closer to the actual dam. From the left shore (NW), the rock seismic velocity increases SW (upstream). It is also maximal in the center of the river, especially upstream. From the right shore (East), the rock seismic velocities are very low for the three seismic lines, possibly due to a shear zone and/or a chemically weathered rock. Considering an excellent rock at 4500 m/s, the Poor to Fair limit could be around 3090 m/s [dashed line]. Similarly, considering an excellent rock at 5000 m/s, the Poor to Fair rock quality limit could be around 3430 m/s [bold line] (cf. ASTM STP 447, pp.154-173, for MRQD evaluation).

From a topographic point of view, the rock elevation seems to be lower on the left side (SW) portion of the river (cf. Figure 8). From the left shore, the rock topography seems to present a trend for a slight dip SW. The right shore presents a steady raise SE, according with the surface topography.

The downstream portion of the area investigated appears more attractive for the new dam axis, as the rock is less weathered than on the other upstream investigated seismic lines. The rock elevation on the left shore (NW) appears to be potentially lower.

In any case, the right shore would have to be investigated by boreholes, as the geophysical results suggest a poor rock quality.

The SL-2-15 (downstream) shows a rock depth under the riverbed around 6.5 meters on the left side, almost outcropping on the right portion of the river center-line, and 2.6 meters on the right side. On the SL-1-15 (middle line), the rock depth under the river could be around 5.9 meters on the left side, 1.7 meter on the right portion of the riverbed center-line, and 3.9 meters on the right side. The SL-3-15 (upstream) suggests a rock depth under the riverbed around 2.2 meters on the left side, almost outcropping on center portion of the river, and 3.5 meters on the right side.

From the shores sides, SL-2-15 suggests 0.5 to 6.2 meters of overburden on the right side, and 1.2 to 3.7 meters on the left side. SL-1-15 results show 0.9 to 5.4 meters of overburden on the right side, and 2.5 to 4.5 meters on the left side. The SL-3-15 suggests 1.3 to 3.0 meters of overburden on the right side, and 1.1 to 2.2 meters on the left side.

All these depths/thicknesses should be considered accurate to around 1 to 2 meters, as long as no geotechnical calibrations are available.

CONCLUSION

CIMA+ mandated Geophysics GPR International inc. to realize seismic refraction surveys over Bob's Lake, upstream of the existing concrete dam, to assess the rock mechanical quality and evaluates its depth from the surface.

As per the seismic refraction results, the rock quality increases from downstream to upstream the actual dam/weir site, especially from the left (NW) shore. The right (SE) shore presented a steady low V_P velocity range. The center-SE of the river had shown a fair rock almost everywhere, especially upstream.

From the shores, the rock elevation seems dipping SW on left shore, away from existing dam. The overburden could be as thick as 0.5 to 6.2 meters on the right shore, and 1.1 to 4.5 meters on the left shore.

Geotechnical assessments are recommended for the rock quality and elevation on the left shore, and especially for the rock quality on the right shore.

This report has been written by Jean-Luc Arsenault, M.A.Sc., P.Eng.

Jean-Luc Arsenault, M.A.Sc., P.Eng.
Project Manager

Figure 1: Regional location of the Site
(source : *Google Maps*™)

Figure 2: Location of the seismic spread
(source : *Google Earth*™)

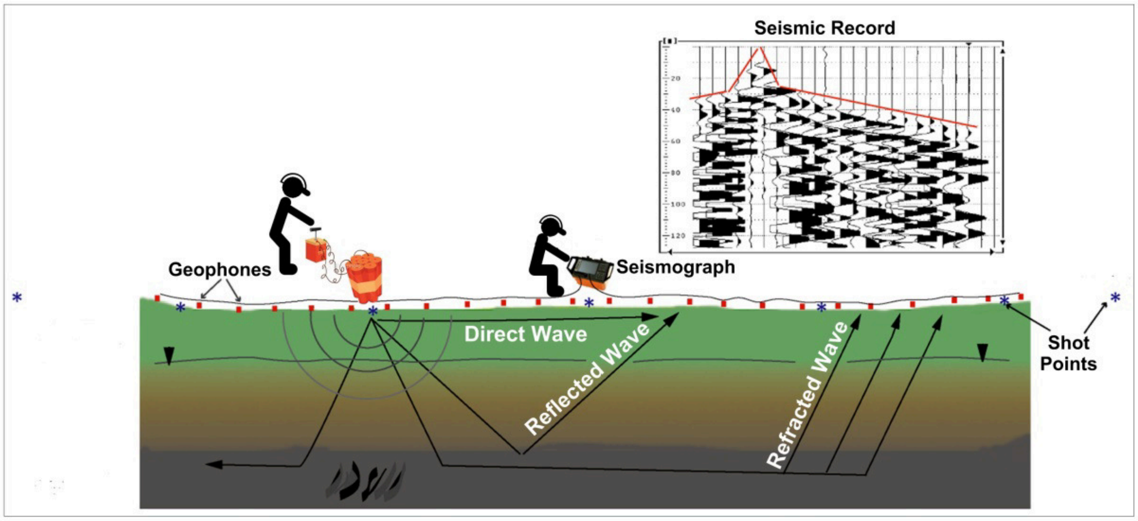
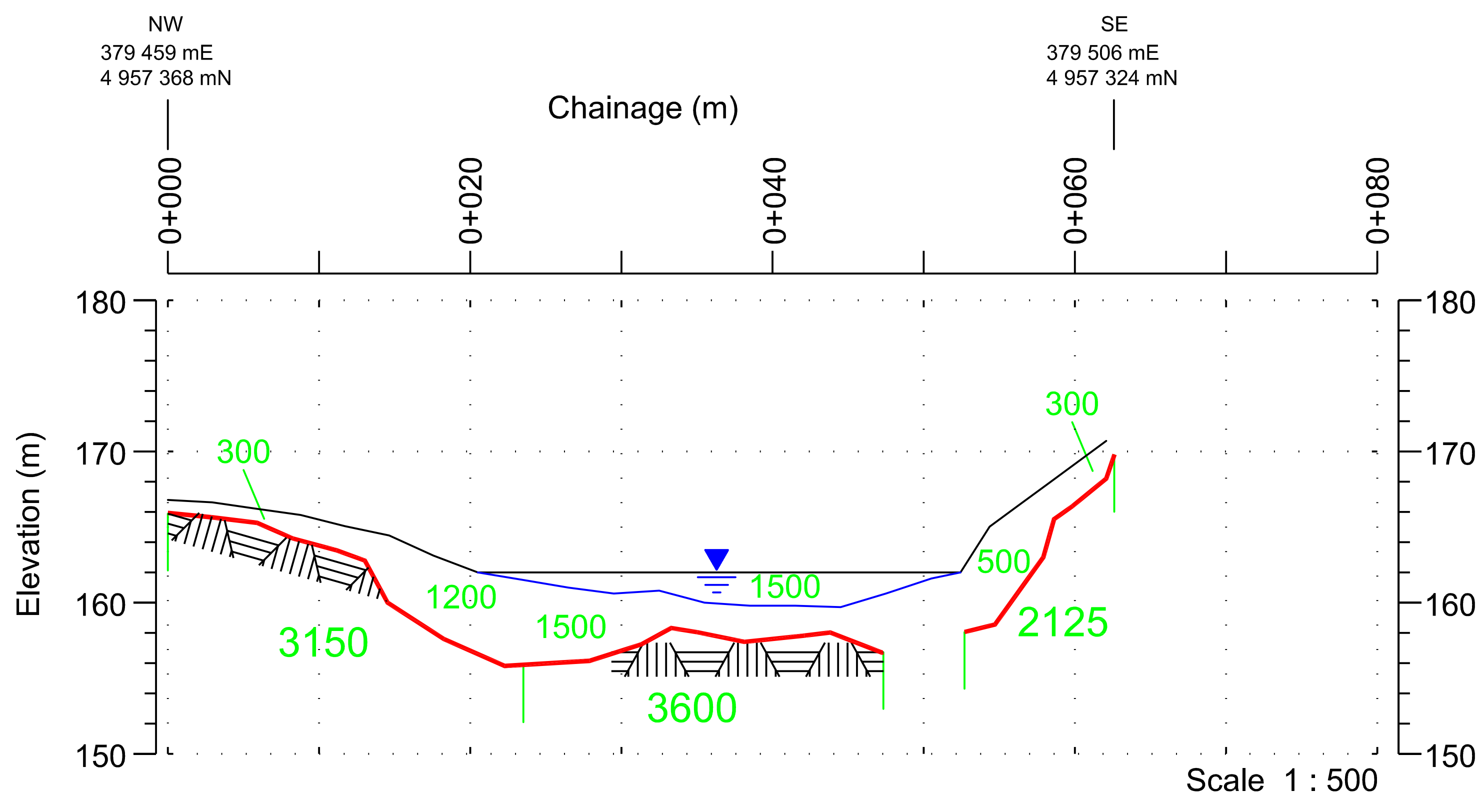


Figure 3: Seismic Refraction Operating Principle

Figure 4: River Crossing Seismic Line with Geophones & Hydrophones

SL-01-15


NW
379 459 mE
4 957 368 mN
SE
379 506 mE
4 957 324 mN
Chainage (m)
0+000
0+020
0+040
0+060
0+080
Elevation (m)
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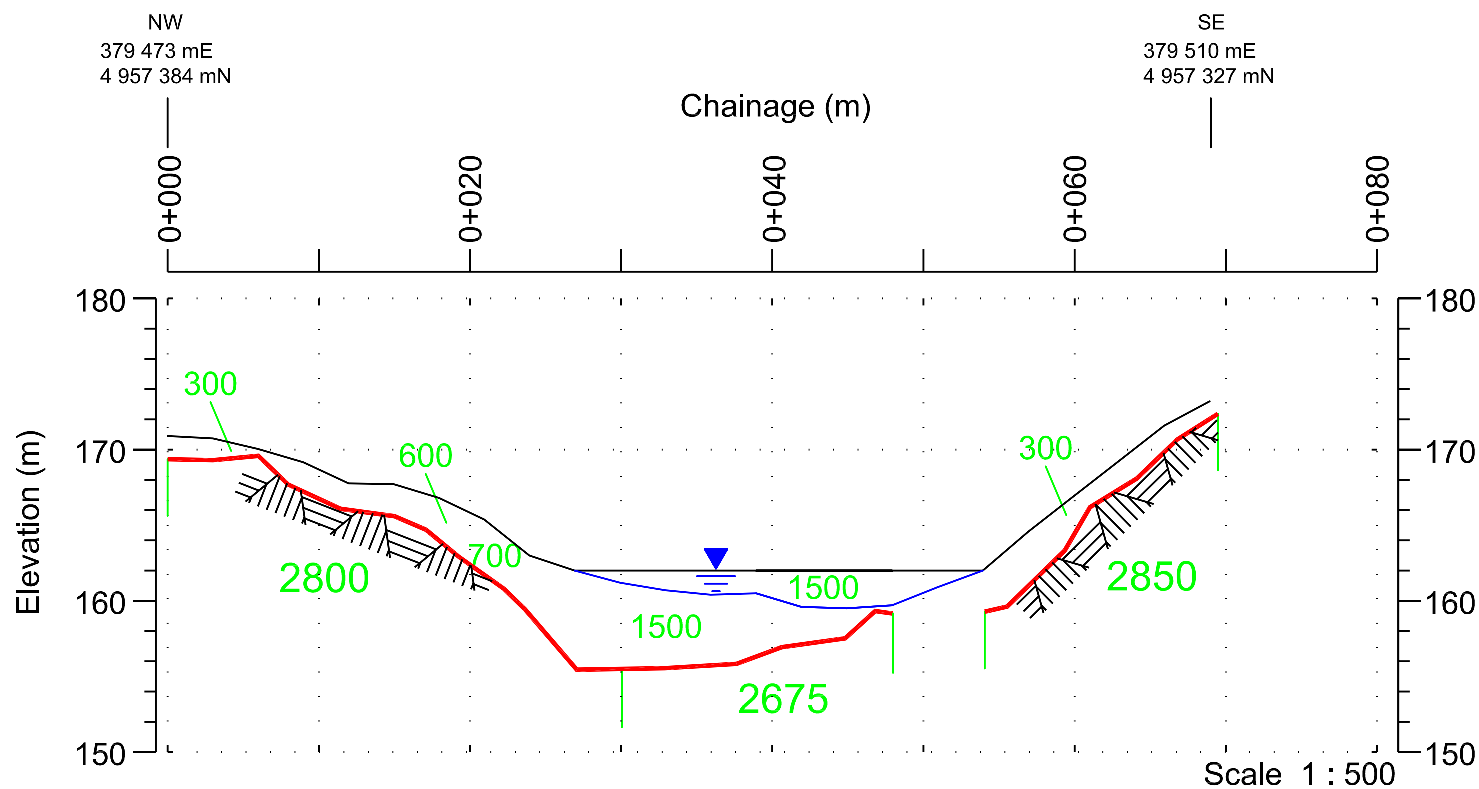
170
160
150
300
300
1200
1500
1500
500
3150
3600
2125
Scale 1 : 500

SL-02-15



NW
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4 957 384 mN
SE
379 510 mE
4 957 327 mN
Chainage (m)
0+000
0+020
0+040
0+060
0+080
Elevation (m)
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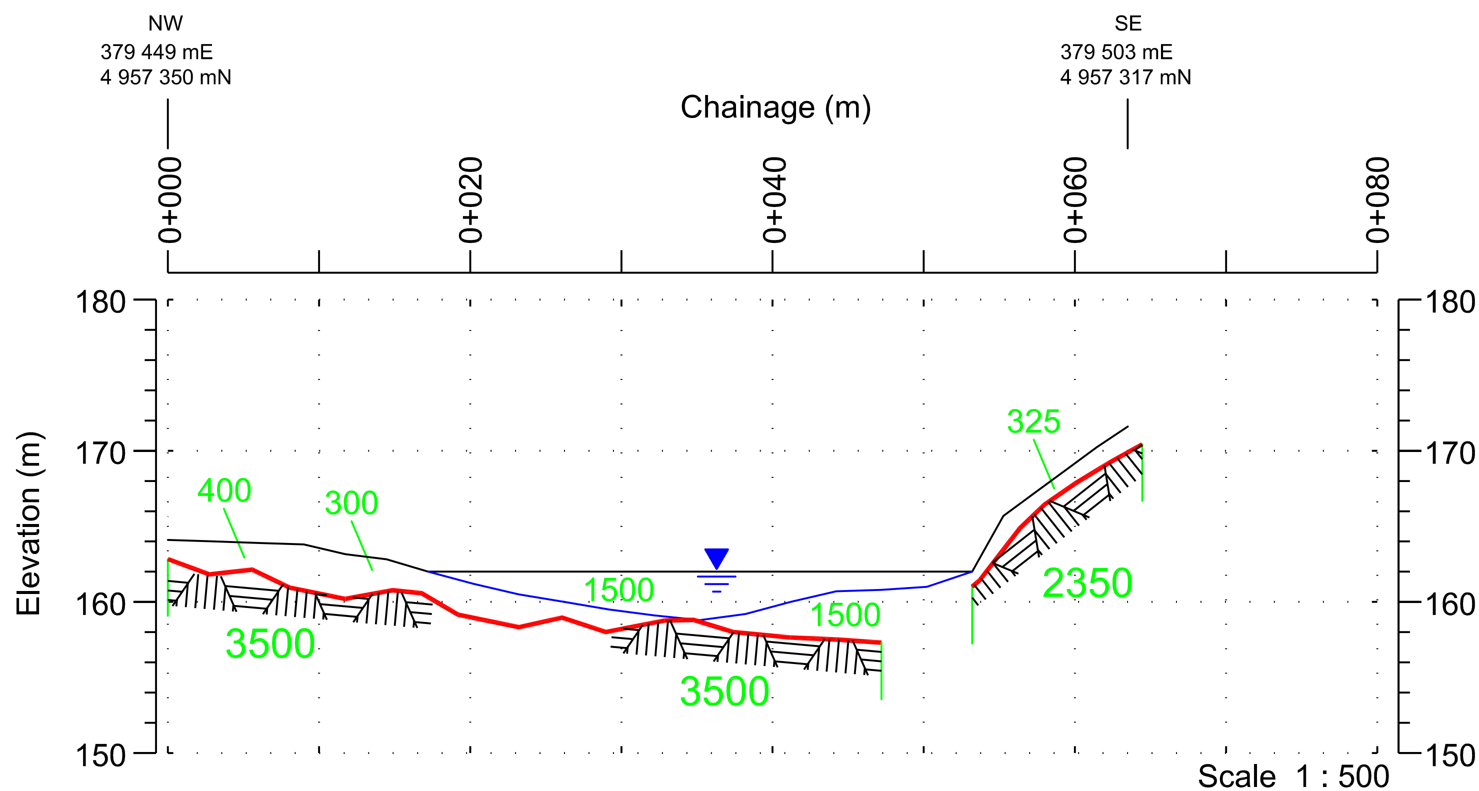
600
700
2800
1500
1500
2675
300
2850
Scale 1 : 500

SL-03-15



NW
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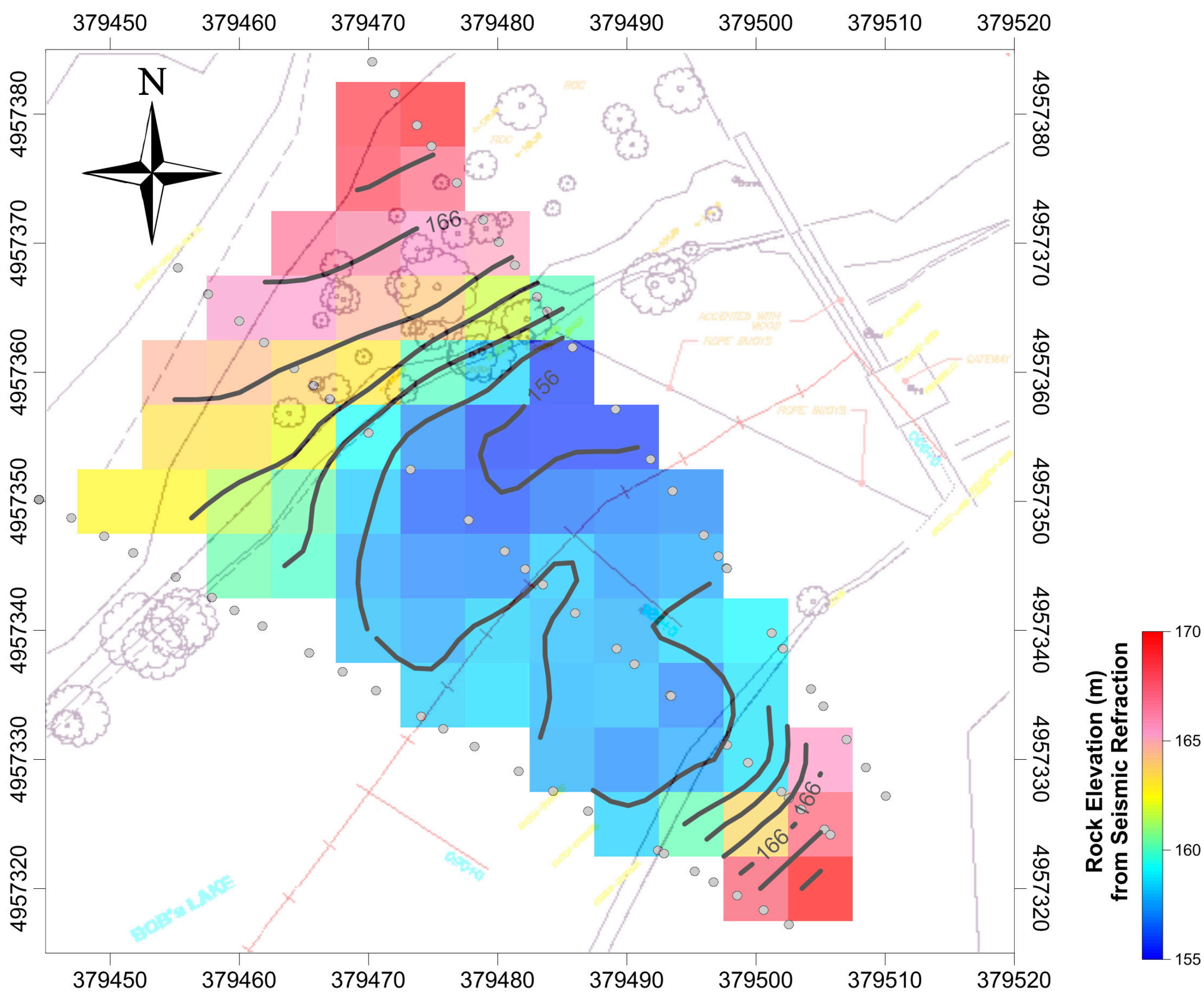
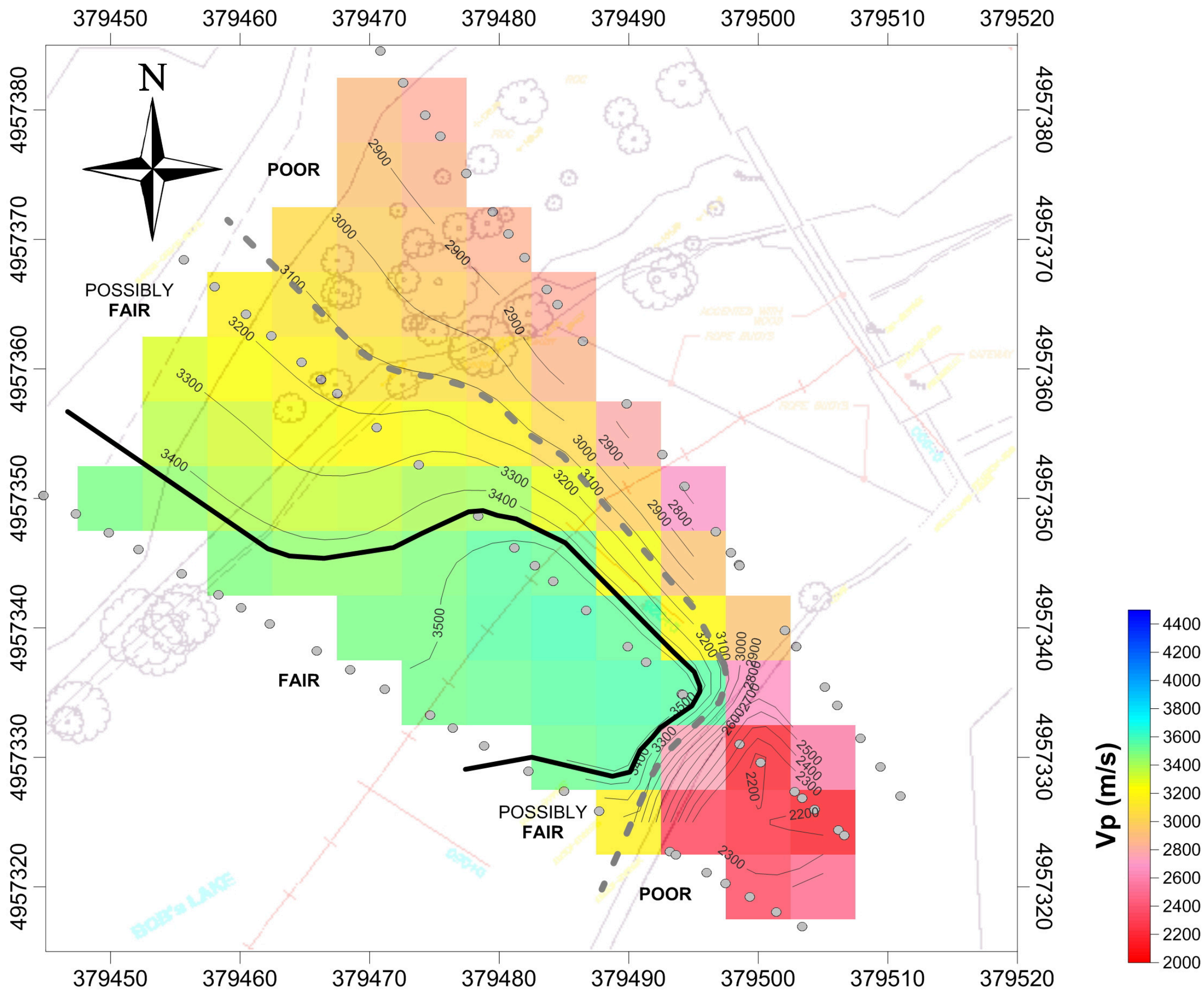
4 957 350 mN
SE
379 503 mE
4 957 317 mN
Chainage (m)
0+000
0+020
0+040
0+060
0+080
Elevation (m)
180
170
160
150
400
300
3500
1500
1500
3500
325
2350
Scale 1 : 500



<u>**Rock Elevation Model from Seismic Refraction Surveys**</u>

Figure 8



Rock Seismic Velocity (Vp) from Seismic Refraction Surveys

Figure 9